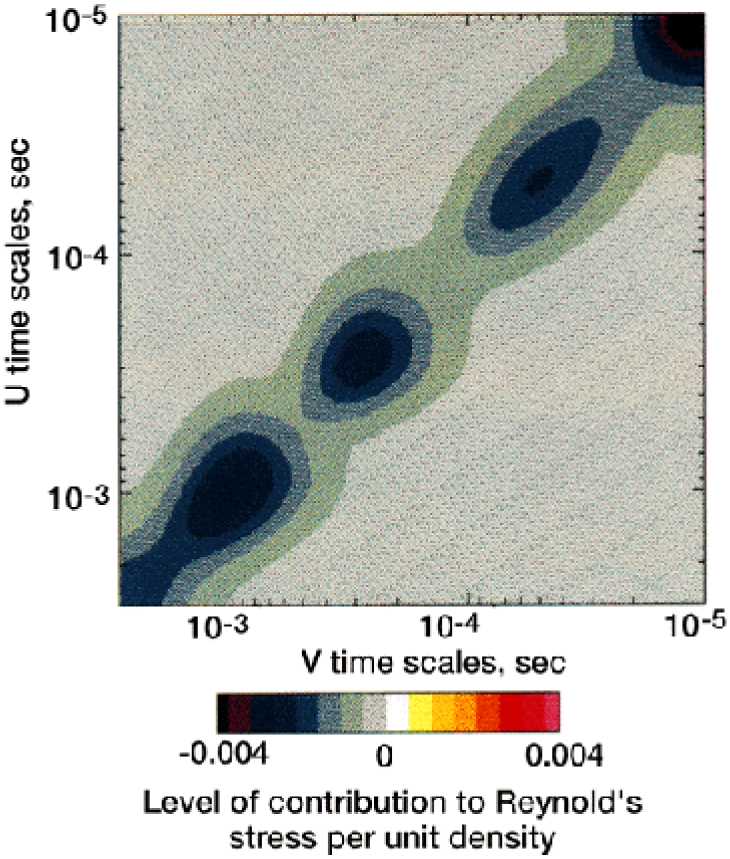
Wavelet Techniques Applied to Modeling Transitional/Turbulent Flows in Turbomachinery

Computer simulation is an essential part of the design and development of jet engines for the aeropropulsion industry. Engineers concerned with calculating the flow in jet engine components, such as compressors and turbines, need simple engineering models that accurately describe the complex flow of air and gases and that allow them to quickly estimate loads, losses, temperatures, and other design parameters. In this ongoing collaborative project, advanced wavelet analysis techniques are being used to gain insight into the complex flow phenomena. These insights, which cannot be achieved by commonly used methods, are being used to develop innovative new flow models and to improve existing ones.

Wavelet techniques are very suitable for analyzing the complex turbulent and transitional flows pervasive in jet engines. These flows are characterized by intermittency and a multitude of scales. Wavelet analysis results in information about these scales and their locations. The distribution of scales is equivalent to the frequency spectrum provided by commonly used Fourier analysis techniques; however, no localization information is provided by Fourier analysis. In addition, wavelet techniques allow conditional sampling analyses of the individual scales, which is not possible by Fourier methods.

The NASA Lewis Research Center developed various wavelet-based algorithms for post-processing the time-trace signals of transitional and turbulent flows (ref. 1). The techniques were demonstrated by analysis of the experimental hot-wire data from the bypass transition experiments conducted at Lewis by Sohn and Reshotko (ref. 2). The figure displays the stress map, a plot exclusively constructed by wavelet processing of two simultaneous signals of the velocity components. It shows the contributions of the various scales to the Reynolds stress at a point in the flow. The structure of this map indicates that dominant scales contribute to the momentum transport--an important conclusion. Conditional sampling showed that the scales that contribute to the transport in the turbulent parts of the signals do not contribute to the energy transport. This information will be used in modeling bypass transition, which is prevalent in turbomachinery flow.



Wavelet-based stress map. U is the streamwise velocity, and V is the normal velocity. (Data are from ref. 2, grid G1, at x = 0.9 in. and y = 0.030 in.)

The techniques were developed at Lewis, in collaboration with Dr. Jacques Lewalle of Syracuse University, under a contract funded by the Lewis Director's discretionary fund. The software developed is available for collaborative work with industry and academia. One collaborative project is currently underway with Dr. D. Wisler and D. Halstead of GE Aircraft Engines in Evandale, Ohio. Under this project, data from turbine and compressor experiments performed at the General Electric Company (ref. 3) are being analyzed at Lewis with wavelet techniques as part of Lewis' Low Pressure Turbine Flow Physics Program.

References

1. Lewalle, J.; and Ashpis, D.E.: Demonstration of Wavelet Techniques in the Spectral Analysis of Bypass Transition Data. NASA TP-3555, 1995.

2. Sohn, K-H.; and Reshotko E.: Experimental Study of Boundary Layer Transition With Elevated Freestream Turbulence on a Heated Flat Plate. NASA CR-187068, 1991.

3. Halstead, D.E., et al.: Boundary Layer Development in Axial Compressors and Turbines. Parts 1-4, ASME Papers 95-GT-461, 462, 463, and 464, 1995.